Fish and amphibian abundance and diversity in two created freshwater marshes

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Abstract

This study demonstrated differences in fish and amphibian species abundances between two created freshwater marshes at the Olentangy River Wetland Research Park in Ohio. Minnow traps were used to sample fish and amphibians from each of three basins located within two wetlands. There were a significantly higher number of bullfrog tadpoles (*Rana catasbeiana*) in the naturally colonized (W2) compared to planted wetland (W1). Tadpole abundances were not significantly different between individual basins within each wetland. All species showed a general trend of decreased abundance from inflow to outflow basins. Green sunfish (*Lepomis cyanellus*) populations were estimated to be 630 ± 524 individuals in W1 and 439 ± 259 individuals in W2. Bluegill sunfish (*Lepomis macrochirus*), hybrid sunfish and golden shiners (*Notemigonus crysoleucas*) were found in both wetlands while goldfish (*Carassius auratus*) were only found in W2. Total fish and green sunfish abundances were similar in both wetlands. Wetland 1 showed no significant difference in species abundances between wetlands while Wetland 2 showed significant differences in green sunfish, total fish, and goldfish abundances between basins.

Introduction

Wetlands provide various functions that are important to both upland and aquatic ecosystems. Shallow water conditions allow for the growth of an abundance of submergent and emergent plant species, as well as high populations of invertebrates that feed on these plant species (Mitsch and Gosselink, 2000). Riparian wetlands in particular can also provide a low energy environment to aquatic fauna for shelter from increased flows during flooding events. The pulsed inputs that these wetlands receive are a major source of nutrients, immigrant species recruitment, and seeds (Mitsch and Gosselink, 2000). These unique conditions allow specialized floral communities to develop and can provide very important habitat, protection and foodstuffs for the life history requirements of many species of animals.

Annual fluctuations of the local climate of a wetland can directly affect the water levels between seasons and from year to year. Species that may have immigrated into a wetland during flood events may later find themselves stranded and cut off from the riverine ecosystems from which they came. In these instances, species populations can be drastically reduced or extirpated. The new individuals of different species recruited from later high-water events (especially fish) will then comprise the foundations of a new population (Zuwerink, 1998).

The Olentangy River Wetland Research Park (ORWRP) contains two 1-ha created riparian wetlands built to imitate freshwater marshes in a riparian zone (Gardner and Johnson, 1996). As an ecosystem scale experiment, the western wetland, Wetland 1 (W1), was planted in 1994 while the other, Wetland 2 (W2), was left to colonize naturally. The park was created for the dual purpose of performing research and educating the public and Ohio State University students about various ecosystem processes and interactions that occur in and around these vital ecosystems.

This study was designed to measure the species richness and abundances of the amphibian and fish communities found in these two wetlands. The goal of this study was to quantify the number of species in each wetland, to estimate the respective populations of fish species, and to check for significant differences in individual species abundances that may exist between the inflow, middle and outflow basins of each wetland.

Methods

Data Collection

Immigration of aquatic life into the two experimental created wetlands is allowed by two means: pumping and flooding. Under normal conditions, two pumps supply equal amounts of water to each wetland at flow rates that fluctuate relative to water level readings taken along the adjacent Olentangy River (Nairn et. al, 1996). One pump is conventional while the second one is a Discflo®. The Discflo® pump is specially designed to allow for the safe passage of small living organisms and propagules into the wetlands. It is through this corridor that the wetlands receive most of their biologic, nutrient, and water inputs. Flooding as a form of recruitment is much more infrequent. Several flood events have connected the river to the wetlands since their creation, the most recent of which was in August 2003

Upon reaching the wetlands, the water flows through three deep basins and exits at the south end of the wetlands into a bioswale. This bioswale merges with the river several hundred yards away and is designed so that no propagules or aquatic organisms may enter the wetlands from this direction

(Kleber et. al, 2001); however, there is a small chance for animals (namely fish) to move between the wetlands via the "y" pipe that connects the two outflows. Kleber et. al (2001) only observed three incidences where fish had utilized this pathway to move between the wetlands.

In order to sample the two wetlands for fish and amphibians, ten aluminum minnow traps were placed in each wetland. Three traps were located in each inflow and outflow basin, and four traps were located in the middle basins (Figure 1). Each trap measured 56 " 2 cm in circumference and 48 " 1 cm in length, with an 8 " 2 cm wide opening (Cochran, 1998). Starting on October 13 and ending on October 24, 2003, minnow traps were dropped into the water and allowed to sit from anywhere between three to 45 hours. Traps were later retrieved and the number of each species of juvenile frogs (tadpoles), adult frogs and fish found in each trap was recorded. All amphibians and fish were identified to species, except for one instance where an unknown shiner of genus Notropis could not be identified. Because our primary interest was in quantifying species abundances and looking for differences between W1and W2, no fish were weighed or measured in this study. All fish had a small fin-snip taken from their tail fin in order to perform a Lincoln-Petersen mark-and-recapture estimation of population. Green Sunfish (*Lepomis cyanellus*, Rafinesque 1819) proved to be the only fish species abundant enough to yield plausible results.

Data Analysis

To reduce bias and account for some sampling efforts that resulted in zero recaptures, we used Bailey's Modification (1952) of the Lincoln-Peterson Index method. Bailey's Modification is as follows:

$$N = \frac{(M)(C+1)}{(R+1)}$$

Where:

N = population size.

M = total number marked from the previous sampling efforts

C = number captured in current sampling effort

R = number of those captured with marks in current sampling effort

Confidence intervals were determined by finding the standard error of the population and multiplying it by the Student's t for a 95% confidence interval at DF = 4 (Brower et al. 1998):

N " (1.96) (SE)

Necessary assumptions for the use of this method are;

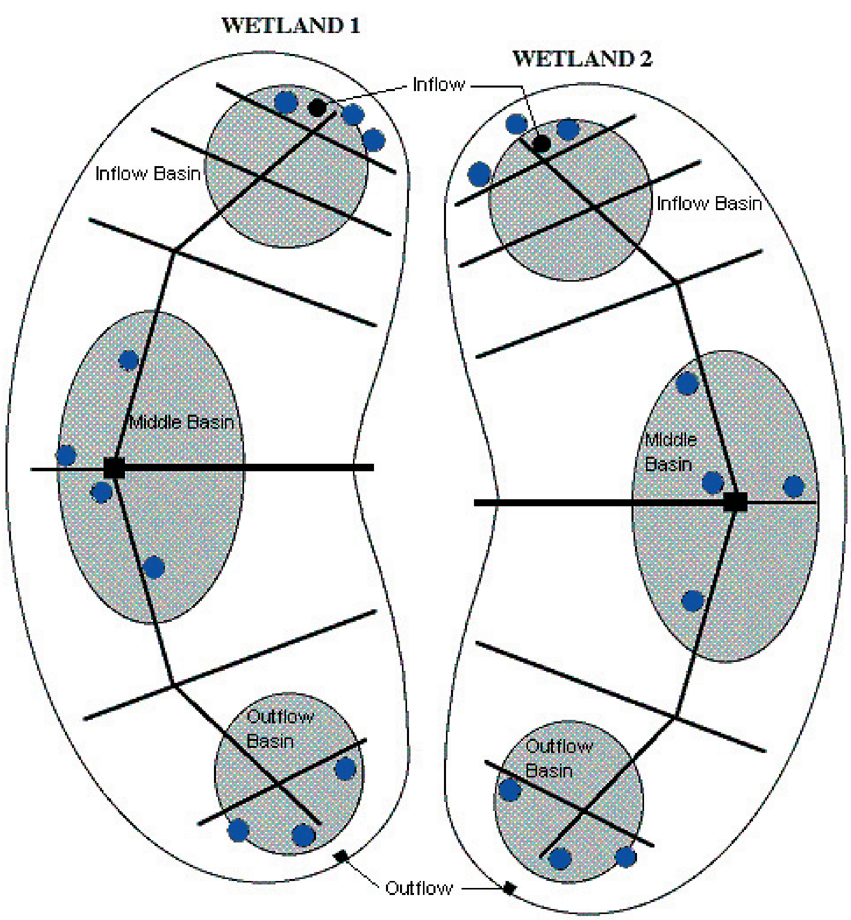

Figure 1. Locations of sampling traps in experimental wetlands

1) All individuals have an equal chance of being captured; 2) The population is closed—there is no recruitment from immigration or reproduction; 3) Marked animals redistribute themselves homogenously with respect to unmarked ones; 4) Marks do not affect the survivability of the fish (Brower et al. 1998). Additionally, it was assumed that no fish were miscounted and no recaptures were overlooked.

Sampling effort was standardized by trap-hours while a square-root transformation was also performed on abundances in order to normalize the distribution of the data (McCune and Grace, 2002). Comparisons of species abundances between wetlands were done with a two-sample t-test while comparisons between basins (inflow, middle and outflow) within each wetland were done with an ANOVA. Because there were three basins within each wetland, a Tukey's Studentized Range (HSD) test was performed to control for the type I experimentwise error rate. All abundance analyses were done using SAS (1999).

Results

Amphibians

Bullfrogs (*Rana catasbeiana*, Shaw, 1802) and leopard frogs (*Rana pipiens*, Pace, 1974) were the only amphibians captured during this study. Four adult bullfrogs were captured in W1 while none were captured in W2. There was a significantly higher ($F = 6.04$, d.f. = 1, $P=0.0148$) abundance of bullfrog tadpoles in W2 than in W1. Sampling efforts yielded a total of 106 bullfrog tadpoles in W1 and more than three times that many (353) in W2. Within individual wetlands, between basin comparisons showed both W1 and W2 to be not significantly different at the .05 level ($F=0.51$, d.f.=2, $P=0.6049$; $F=2.60$, d.f.=2, $P=0.0787$) in Bullfrog tadpole abundances (Table 2).

Two adult Leopard frogs were captured in W2 while none were captured in W1. No leopard frog tadpoles were present in any of the sampling efforts in either wetland (Table 1).

Fish

Three fish species were found in W1. These species included bluegill sunfish (*Lepomis macrochirus*, Rafinesque, 1819), green sunfish (Lepomis cyanellus, Rafinesque, 1819) and golden shiner (*Notemigonus crysoleucas*, Mitchill, 1814). In W2, five species of fish were found. In addition to those mentioned above, W2 also included goldfish (*Carassius auratus*, Linnaeus 1758) and an unidentified shiner most nearly resembling a member of the genus *Notropis* (Rafinesque, 1819). Green sunfish was by far the most numerous species in both wetlands (Figure 2).

An analysis of standardized samples showed both green sunfish and total fish abundance to not be significantly different ($F=1.51$, d.f.=1, $P=.2202$; $F=0.73$, d.f=1, $P=.3930$) between the two wetlands. Within W1, no significant differences existed between basins for green sunfish ($F=0.51$, d.f =2, $P=0.6004$) and total fish ($F =0.37$, d.f. = 2, $P<.6913$) abundances. Wetland two, however, showed significant differences of green sunfish ($F =11.69$, d.f. = 2, $P < 0.0001$), total fish ($F =8.51$, d.f. = 2, $P = 0.0004$) and goldfish ($F = 3.11$, d.f. = 2, $P = 0.0487$) abundances to exist between basins (Figure 3).

Tukey's Studentized Range (HSD) tests were then used to find where the significant differences existed between basins. The test showed green sunfish abundances to be significantly different between the inflow basin and both the

Table 1. Number of individuals surveyed in current and past amphibian studies (Modified from Hensler and Cochran, 1999).

Sampling Date	Species		W1	W2
May—June 1998	Bullfrog			
		Mature	2	1
		Larval	19	27
October 1998	Bullfrog			
		Mature	0	0
		Larval	418	85
Fall 2000	Bullfrog			
		Larval	260	3,600
Spring 2001	Bullfrog			
		Larval	670	2,900
October 2003	Bullfrog			
		Mature	4	0
		Larval	106	353
	Leopard Frog			
		Mature	0	2
		Larval	0	0

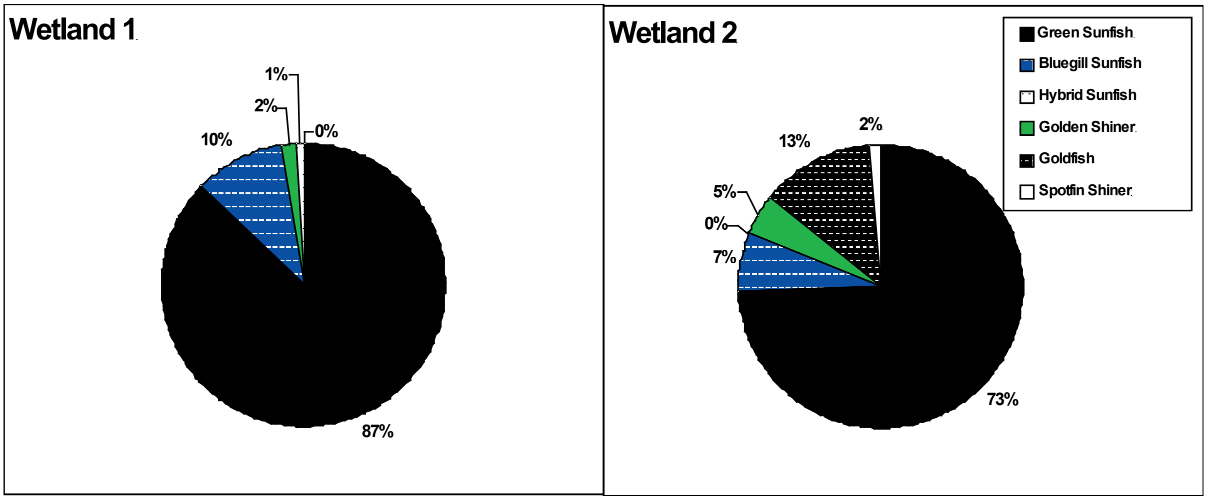

Figure 2. Percent abundance of each species by number captured with minnow traps from October 13 to October 24, 2003.

Table 2. Significant differences in numbers of individuals between wetland basins within both wetlands at the .05 confidence level. Letters indicate basins with similar abundances.

Wetland / Category	Basin	Significance	Basin	Significance	Basin
Total Fish					
W1	InflowA	=	middleA	=	outflowA
W2	InflowA	>	middleAB	=	outflowB
Green Sunfish					
W1	InflowA	=	middleA	>	outflowA
W2	InflowA	>	middleB	>	outflow B
Goldfish					
W1	N/A	=	N/A	>	N/A
W2	Inflow A	=	middle AB	>	outflow B

middle and outflow basins (Table 2). Total fish abundances were significantly different between the inflow basin and the outflow basin, with the middle basin being statistically similar to both. Goldfish abundances were also significantly different between the inflow basin and the outflow basin, with the middle basin again being statistically similar to both (Table 2).

Estimates of green sunfish populations from mark and recapture efforts were 630 " 524 (CI = 95%) in W1 and 401" 259 individuals (CI = 95%) in W2 (Table 3). The large standard error observed in both instances (Figure 4) can be attributed to the relatively small sample sizes obtained during each sampling effort.

Discussion

On the last day of sampling, captures for green sunfish were two to three times larger than the averages for all previous sampling efforts. In some instances the number of bullfrog tadpoles sampled on the last day was as much as 10 times larger than the averages from the previous sampling efforts. These increased abundances have been attributed to substantial lowering of the water levels that occurred in both wetlands between the second to last and last day of sampling (ORWRP water quality data, 2003). The lower water levels (~ -15%) are presumed to have caused an increase in the concentration of the aquatic fauna in the wetlands, thus causing an increase in the number of fish and bullfrog tadpoles sampled. Because this increase was observed across all basins, data collected on the final day of sampling was included in the study. However, because of the high variances that this imparted to the rest of the bullfrog tadpole abundance data, expected differences in tadpole abundance between basins were not observed (Figure 3).

The higher numbers of tadpoles in W2 compared to W1 is dissimilar to the 1998 findings of Hensler and Cochran. Their study found a significantly larger number of bullfrog tadpoles in W1 than in W2. However, in a more exhaustive study done by Gifford (2001), it was found that W2 had many more bullfrog tadpoles than W1 in both autumn and spring. Gifford attributed this observed difference to the larger fluctuations of dissolved oxygen that occur in the historically more productive, and hence more detritus producing W2.

Bullfrogs lay eggs from February through July and some of their tadpoles over-winter before metamorphosing into adults (Conant and Collins, 1998). This may explain the noticeable size differences observed between individuals in the field. Larger bullfrog tadpoles were likely to have hatched earlier in the spring while their smaller counterparts had hatched more towards summer.

The observed absence of leopard frog tadpoles may also

Table 3. Population estimates for green sunfish in W1 and W2 with a 95% confidence interval.

Wetland / Date	Captured	Recaptured	Total Marked	Pop. Estimate
W1				
10/15/2003	23	—	—	—
10/17/2003	3	0	23	132 " 104
10/19/2003	25	4	26	135 " 97
10/20/2003	2	2	47	47 " 0
10/21/2003	6	1	47	165 " 136
10/22/2003	13	2	52	243 " 211
10/24/2003	39	3	63	630 " 524
W2				
10/15/2003	15	—	—	—
10/17/2003	9	1	15	75 " 76
10/19/2003	13	2	23	107 " 93
10/20/2003	2	1	34	51 " 33
10/21/2003	6	0	35	245 " 314
10/22/2003	11	1	41	246 " 254
10/24/2003	54	6	51	401" 259

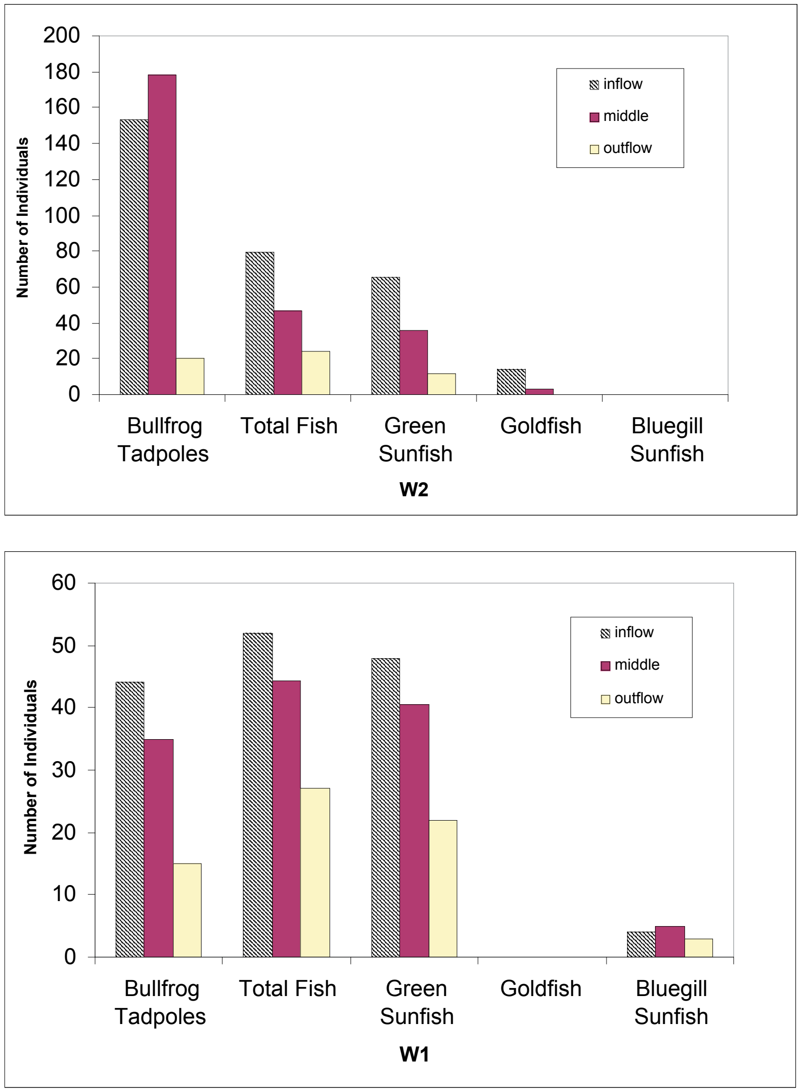

Figure 3. Total number of individuals of each species that were sampled in the three basins of W1 and W2.

be attributed to their life history characteristics. Leopard frogs metamorphose into adults in late July and early August (Conant and Collins, 1998); well before the beginning of this study. Because amphibians have only recently been given attention in annual studies, further research should focus on quantifying changes in seasonal and annual fluctuations that may exist between leopard frog and bullfrog tadpole abundances.

Although only a few species abundances were found to be significantly different between wetland basins, a general decrease in all species was observed from the inflow basin to the outflow basin in both wetlands (Figure 3). These findings parallel those of previous studies. Hensler and Cochran (1998) found fish abundances to differ significantly among basins within each wetland for May to June and October. This observed decline has generally been attributed to changes in water column characteristics from the inflow to the outflow of both wetlands.

Observed abundances of fish species other than green sunfish and goldfish were too low to test for differences between wetlands and basins within wetlands. According to the Ohio EPA (Unpublished data, 1991), the most abundant species at river mile 3.6 of the Olentangy River was bluegill sunfish (13.72%), followed by largemouth bass (*Micropterous salmoides*, Rafinesque, 1819) (7.35%), golden shiner (6.37%), and common carp (3.77%). Green sunfish was only found to be the sixth most abundant species in the Olentangy River (EPA, 1991). Though as many as 10 different species of fish have been found to be entering the wetlands via the pumps (Gardner and Johnson, 1995, 1996), studies over the past seven years have shown common carp (*Cyprinus carpio*), green sunfish, and on occasion, fathead minnow (*Pimephales promelas*) to be the most prevalent species in the wetlands (Hensler and Cochran, 1998 and 1999; Custer et. al 2000, Elrott and Mitsch, 2000). This can most nearly be attributed to the beneficial adaptations

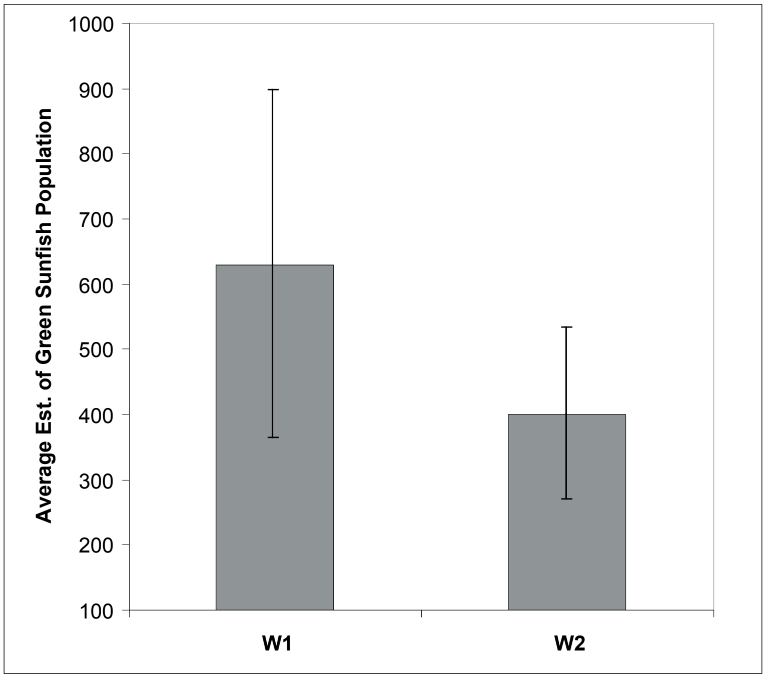

Figure 4. Estimations of green sunfish population size in each wetland after 11 days of mark-and-recapture sampling. Large standard error bars indicate no significant difference between the two wetlands.

that these species have for dealing with the various stresses encountered in wetland environments (dramatic fluctuations in water levels, high and low water temperature and pH, and dissolved oxygen depletion). For example, Mittelbach and Osenberg (1993) report that juvenile bluegill sunfish require invertebrate resources found in weedy littoral areas, while adults need open water to feed on plankton. This may explain why only a few small specimens of bluegill sunfish were observed in this study and in past studies (Hensler and Cochran, 1998).

Comparatively, green sunfish, can reach maturity and begin reproducing in stressful environments at a very early age and at very small sizes (Troutman, 1981, Carlander 1950). They are also known to be tolerant of many of the stresses associated with wetland environments. This may explain why green sunfish have been the most prevalent fish species in both wetlands on an almost annual basis (Table 4). In particular, their dominance in W2 (with the exception of 2 years) might be explained as an increase in secondary productivity, as the primary productivity in W2 has been historically higher than W1 (Mitsch and Gosselink, 2000). The increased detrital production that results from the primary productivity would seem to indicate that like bullfrog tadpoles, green sunfish tolerance of low dissolved oxygen levels may also explain their historic successes in W2.

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Table 4. Number of each species of fish found in past wetland studies at the Olentangy River Wetland Research Park (Modified from Kleber et. al, 2001).

Sample time	Fish species	W1	W2	Reference
October 1996	Green sunfish	27	30	Gutrich et al., 1997
October 1997	Green sunfish	1294	1903	Cochron, 1998
	Common Carp	672	20	
	Fathead minnow	3	0	
	Bluntnose minnow	1	3	
	Orangespotted sunfish	18	3	
May-June 1998	Green sunfish	192	281	Hensler and Cochran, 1998
	Common Carp	179	33	
	Fathead minnow	2	0	
	Pumpkinseed	2	0	
	Creek chub	2	0	
October 1998	Green sunfish	12	52	Hensler and Cochran, 1999
	Fathead minnow	0	2	
	Bluegill	0	1	
April – May 1999	Green sunfish	93	13	Custer et al., 2000
	Fathead minnow	69	17	
	Bluntnose minnow	3	0	
	Creek chub	0	2	
October –Nov. 1999	Green Sunfish	47	310	Ellrott and Mitsch, 2000
	Fathead Minnow	0	1	
October—Nov. 2000	Green Sunfish	874	154	Kleber et. al 2001.
October, 2003	Green Sunfish	136	124	Smith, 2003
	Bluegill Sunfish	12	8	
	Goldfish	0	17	
	Golden Shiner	1	6	
	Hybrid SF	1	0	
	Unknown Shiner	0	2	

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